



Multi-Function, Multi-Mode Digital Avionics (MMDA) Survey and Assessment of Military Avionics

ACAST Workshop
Report Presentation

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- Introduction
 - Study Team:
 - » CNS
 - » ViaSat Government Systems (Mike Kocin)
- SOW Tasks and Report
- Recommendations

Statement of Work



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- Assess the applicability to civil aviation of the architectures, components and technologies being developed under the Department of Defense's Joint Tactical Radio System (JTRS) program. The Contractor shall specifically assess the applicability of the JTRS Software Communications Architecture (SCA) and the planned JTRS airborne cluster developments to civil MMDA applications.
- Assessment shall include as a minimum an identification of:
 - JTRS waveforms and/or architectures that meet current and emerging avionics standards;
 - Areas of concern or challenge where JTRS does not address civil avionics standards;
 - Certification aspects facing the use of JTRS waveforms and/or SCA architecture in civil aviation; and
 - Working groups and key individual contacts associated with certification aspects of aircraft equipped with JTRS capability to operate in FAA-controlled airspace.

Report Content





- Executive Summary
- Survey & Assessment
 - Task 2: Current and Near Term CNS Architecture
 - Task 3: Product & Architecture Survey
 - Task 4: Analyzing Current Efforts for the Roadmap to MMDA
 - Task 5: Analysis of Past and Current Program Applicability
- Recommendations
 - JTRS waveforms and/or architectures that meet current and emerging avionics standards;
 - Areas of concern or challenge where JTRS does not address civil avionics standards;
 - Certification aspects facing the use of JTRS waveforms and/or SCA architecture in civil aviation; and
 - Working groups and key individual contacts associated with certification aspects of aircraft equipped with JTRS capability to operate in FAA-controlled airspace.
 - Design Guidance for MMDA development
- Contact Information



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Roadmap to a MMDA Architecture



Architectural Study Philosophy



- Application of military technology transported to the commercial world
 - JTRS is the cornerstone of military software defined radios
- Examine past programs with Multi-mode, Multi-Function system performance
 - Multiple Bands, not just VHF/UHF
 - Multiple functionality including CW and pulse waveforms



Leading Legacy Military Programs



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Leading to MMDA Architecture

- Architectures examined:
 - Integrated Architecture Development Process
 - Advanced Tactical Fighter (F-22)
 - Joint Strike Fighter (F-35)
 - JTRS
 - MMDA based on military guidelines and lessons learned
- Analysis and examination included:
 - SCA/CORBA Requirements
 - Integrated, common, open architecture
 - Upgradeability
 - Key Technical contribution
 - Key Technical Failures or shortcomings
 - Key Lessons Learned



Architectural Assessment Getting Started

Generic Military Technical Architecture



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Accelerating CNS **Black Side** Receive De-Channel Channel Network RF nodulation **Formatting** Decode **Processing Processing Antenna Processing** Processing **Processing** RF **Processing Transmit** Channel Channel Modulation **Network** RF **Formatting Encode Processing Processing Processing Processing Processing** Information Network Security **Antenna** RF Timing (INFOSEC) Control **Pointing** Control Control Processing Source Source Network Decode **Formatting Processing Processing** Human **Processing** Machine Interface Channel Processing Source Network **Encode Formatting Processing Processing Processing** Red Side



Architecture Development Process



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(History used as a roadmap to the future)

- Lessons learned from historical programs
 - Performance successes
 - Hardware and software inconsistencies
 - Architectural changes coupled with technological innovation
- JTRS influences and commonality
 - SCA/CORBA
 - Well defined software interfaces
 - Open hardware architecture and bus structure
 - Well defined hardware interfaces



Architecture Development Process



- Identify all sensor functionality that is to be implemented in the integrated architecture:
 - Communications
 - Navigation
 - Surveillance
- Identify operational use of CNS functionality to determine functional simultaneous requirements
 - Terminal
 - Departure
 - En Route (CONUS/Transoceanic)
 - Approach/Landing/Runway
 - Other



Architecture Development Process (Continued)



- Identify and group key functional performance characteristics required by the CNS functionality
 - Frequency Band
 - Bandwidths
 - Selectivity
 - Latency
 - Transmit Power
 - Modulation
 - Data Throughput Rates
 - Etc
- Determine common architecture elements that will provide the capabilities identified for each group

Architecture Development Process (Continued)





- Experience in the development of integrated avionics has shown that when a function has a unique (only) performance characteristic that is either costly to implement, or its implementation is so trivial, common hardware processing elements are not assigned to the functionality. Examples:
 - Surveillance Transponders (ATC/TCAS/Mode S)
 - Some Radar Altimeters
 - HF PA/Couplers
 - GPS Receivers
 - Very Wideband Signals
 - Fast Frequency Hopping Signal Structure
- This approach removes the cost to implement unique functionality from the common module design or does not "waste" a multifunctional module to perform a relatively simple process

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Architecture Development Process (Continued)



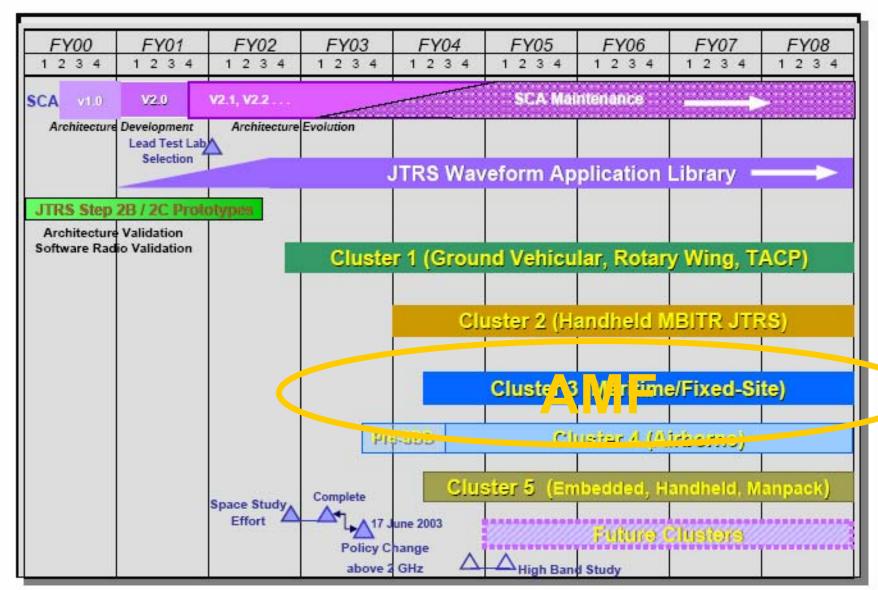
- Design the architecture with the minimum set of architecture elements that just meet all the simultaneity requirements for all Operational Need Conditions
 - Common processing elements allow for functional reprogramming with alternate software downloads and reconfigurable hardware
 - Higher priority functionally can be maintained in the event of a failure of a hardware element (i.e. Soft Failures or Gradual Degradation)
- Last, but not least, the architecture hardware/software infrastructure is identified and designed (i.e. the "glue" to make everything work together)
 - Data And Control Busses
 - Low Latency Discretes
 - Terminal and Resource Control
 - External And Internal Interface Control
 - Security Features
 - Spectrum and co-site management, including certification issues
 - BIT And maintainability



JTRS Program



JTRS Program Schedule





JTRS Military Tactical Airborne Architecture Implementation For MMDA



- Civil aviation does fall within the JTRS vision statement
 - Common User Interfaces across all implementation domains
 - Common Waveform Application Interfaces to all operating systems through the use of middleware (provides for software portability across implementations)
 - Adherence to SCA Specifications
- Functionally, military implementation is consistent with MMDA
 - Voice functionality similar
 - Military data links include AJ, LPI and security features
 - JTRS implementation of ATCB/Mode S/TCAS Type Transponders and interrogators questionable (Civil Aviation May Need To Develop)
 - External waveform unique PA's and Antenna Interfaces
- Capabilities of military resources may be costly "over kill" for civil aviation
 - Highly capable AJ/LPI/Multi-Band/Multi-BW/Multi-Mode Transceiver
 - » Includes Both Receiver/Exciter And Modem Digital Processor
 - Embedded programmable crypto
 - » Multiple Single Level Security (MSLS)
 - » Air Force's Electronic Key Management System (EKMS)



Forming A MMDA Architecture

Overview



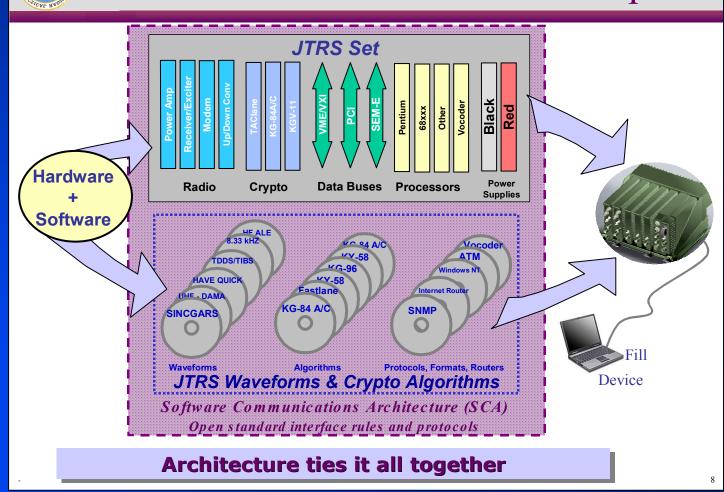
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Software Defined Radio Concept



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Processing Elements Developed/Proposed For Current Integrated Avionic Architectures



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F-22/JSF/Comanche

- L-Band AIU/Preselector
- UV-Band AIU/Preselector (Includes UV Guard Fixed Tuned Receivers)
- L-Band T/R SW & PA
- UV-Band T/R SW & PA
- Satcom AIU/LNA
- L-Band Multi-Mode Transceiver (900-2000 MHz)
- UV-Band Multi-Mode Transceiver (30-400 MHz)
- IFF/Mode S Transponder
- Multi-Channel Black Preprocessor
- Common Red Data Processor (with embedded security module)
 - » {note: above two is being integrated into a single module}
- Avionics Trusted Interface Controller
- Red and Black Data Busses
- RF Control Bus
- External Control Bus
- Low Latency Discretes

MIDS-JTRS

- TACAN/GPS SRU
- Link 16 Transceiver
- Link 16 Transmitter/AIU
- External PA/AIUs (as required)
- 2-2000 MHz Multi-Mode Transceiver
- Preprocessors (FPGA/DSP Based)
- Front End Controllers (Black GPP)
- Data Security/Key Manager/Trusted Gateway
- Red GPP/Avionics Interface
- Red and Black Data Busses
- Control Busses
- Low Latency Discretes



Civil Aviation Airborne Domain MMDA Implementation Recommendation



- Civil Aviation Does Fall Within The JTRS Vision Statement
 - Common User Interfaces Across All Implementation Domains
 - Common Waveform Application Interfaces To All Operating Systems Through The Use Of Middleware (Provides For Software Portability Across Implementations)
 - Adherence To SCA Specifications
- Separate Receiver/Exciter And Modem Digital Processor
- Transceiver And Crypto Simplified To Reduce Cost Of Ownership
 - Meets Civil Requirements Only
- User Interface Assets Scaled To Meet The Civil Environment

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JTRS Architecture Assessment and Applicability to MMDA



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- JTRS architecture will meet civil standards especially with voice and VHF data waveforms
- Additional waveform technology needs development for Navigation and Surveillance, current waveforms are voice focused

– VOR/DME

- ILS

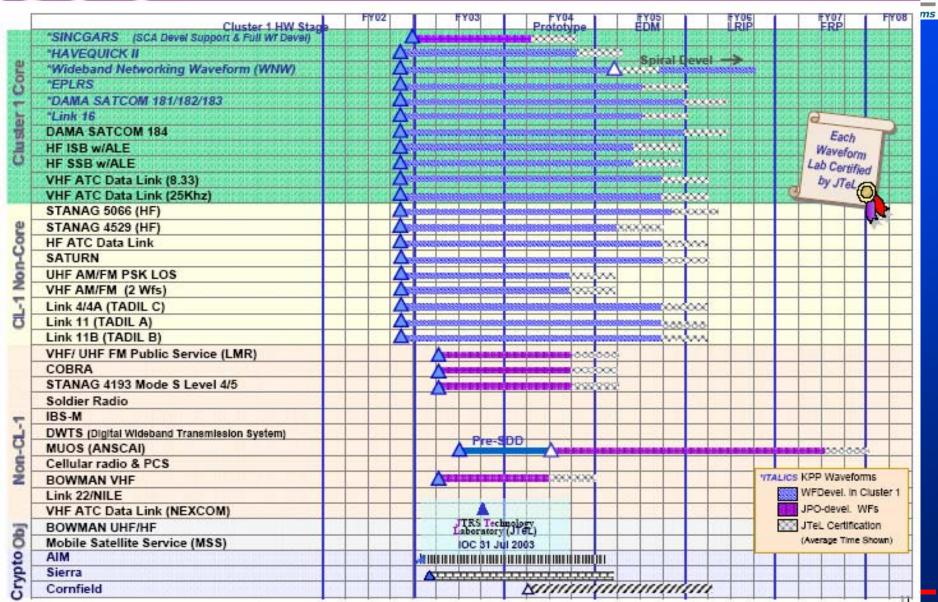
- GPS

- TRR

- Wideband Data Link needs to be the cornerstone of a Civil JTRS type of design
- Alignment of JTRS and MMDA schedules critical to leveraging Military technology for commercial application
- Implement Layered approach to architecture allowing upgrades to be implemented with less impact on the basic radio design
- Certification path to FAA criteria (SC-200) needs to be defined



Joint Waveform Schedule



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JTRS Waveforms - Civil Applicability - 1/2



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Waveform (Short ORD Name)	OR D ID	Frequency Band	Normal Channel Bandwi dth	Information Voice and/or Data Rates	Criteria [and Comments in brackets][Latest Version of Documents Shall be Applied]
HF ATC Data Link	W1 4	(T) 2 - 30 MHz (O) 1.5 - 30 MHz	3 KHz	Voice (A) & Data 300, 600, 1200, 1800 Bps	Air Traffic Control (ATC). RTCA DO-265, ARINC 635-3 & -735-3, and FAA TSO-C31d compliant TDMA and FDMA. Objective to 1.5 MHz in compliance with STANAG-4203, QSTAG-733, et al. [Packet data.]
VHF-AM ATC	W1 5	(T) 118 - 137 MHz (O) 108 - 137 MHz	8.33 KHz [Include s 25 KHz]	Voice (A) 16 Kbps	Air Traffic Control (ATC). RTCA DO-186A & ARINC 716 compliant and NAS Architecture with future 108 - 118 MHz (presently VOR/ILS and emergency ATC voice). Navigation uses may require increased reliability and availability. Include legacy 25 KHz plus European 8.33 KHz. Includes VHF guards (121.5 & 123.0 MHz et al) & inband signals (ELT & SELCAL et al).
VHF-AM ATC Extended	W1 6	108 - 156 MHz	25 KHz	(T) Voice (A) (O) VOR/ILS Nav (A)	Air Traffic Control (ATC), VHF Omni-Range (VOR), and Instrument Landing System (ILS). QSTAG-706 & RTCA DO-186A & -195 & -196 & ARINC 716 complaint, and NAS Architecture with future 108 - 118 MHz (presently VOR/ILS and emergency ATC voice). Navigation uses may require increased reliability and availability. Includes extended legacy 25 KHz. Includes VHF guards (121.5 & 123.0 MHz et al) & inband signals (ELT & SELCAL et al).
VHF ATC Data Link (NEXCO M)	W1 8	118 - 137 MHz	25 KHz	Voice (D 4.8 Kbps) & Data 31.5 Kbps	RTCA DO-186A & -224A compliant, a.k.a. VDL 2 & 3. Next Generation Communication (NEXCOM) FUW FAA CONUS and overseas & military ATC.



JTRS Waveforms – Civil Applicability -2/2



Waveform (Short ORD Name)	OR D ID	Frequency Band	Normal Channel Bandwi dth	Information Voice and/or Data Rates	Criteria [and Comments in brackets][Latest Version of Documents Shall be Applied]
STANAG 4193 Mode S Level 4/5	W2 3	1030 & 1090 MHz	3.5 MHz / 3 MHz	Data 689.7 Bps (1.45 µsec PCM) IFF Family, and 9.6 to 128 Kbps Mode S, plus others per Standards.	Fully compliant with STANAG 4193 including Mode Select (Mode S), Levels 5 & 4 lower. Threshold includes both transponder s and interrogators on platforms and at low transmit powers. Objective includes upgrade to high power (ground-based and airborne warning et al) interrogators. Includes Mark X & XIIA with all Identification Friend or Foe (IFF) and Selective Identification Feature (SIF) Modes 1 through 5 and A & C, and ACP-160 and ICAO Annex 10 compliance. Includes civil secondary Air Traffic Control Radar Beacon System (ATCRBS), Airborne Collision Avoidance System (ACAS) and Traffic Alert & Collision Avoidance Systems (TCAS), and Automated Dependent Surveillance-Addressable (ADS-A) and Broadcast (ADS-B) functionality. Includes supporting interface to GPS and other systems for flight navigation and timing data. ADS requires interface to SATCOM, VHF Data Link, and other alternate channels IAW platform capabilities and mission needs. Includes generation of, and detection and alarm on, emergency messages, including ATCRBS (7700 emergency, 7600 communication failure, et al) and special military (4X et al) codes.



Area of Concern/Challenge



- What will the JTRS concept packaged for civil applications cost?
- Will civil aviation (air transport, business and general) adopt software portability and open standard architecture concept of the JTRS as the means to achieve interoperability?
- Is there any certification legacy that can be claimed upon completion of the military program?
- Can the JTRS be developed to use the ISO TP4/CLNP protocols of the currently defined ATN?
- Is the multi-level certify concept with the JTRS useful to the civil aviation industry?
- Will the aviation community support ask for a buyers set of standards that allows the JTRS set to be swappable item between aircraft?

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Key Recommendation of the Study



- NASA should proceed with a one of the MMDA prototypes being based upon the JTRS technical approaches:
 - Open SCA Architecture is a proven approach
 - Capitalizes and use the technology legacy
 - Should include as part of the prototype effort a "design to aviation acceptable unit cost analysis" task (viewed in the network-centric context)
 - Should foster a path to certification
- NASA should foster aviation industry standardization activity:
 - Capitalize upon the work of the SDR Group
 - Establish industry approach to waveform portability
 - Standardize the form, fit and function including the SCA architecture within the aviation community
 - Seek to resolve the path to certification issues with the JTRS
 Program



Contact Information



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Computer Networks & Software, Inc.

7405 Alban Station Ct., Suite B-215 Springfield, VA 22150-2318 703-644-2103 www.CNSw.com

> Chris Wargo 443.994.6137 (cell) chris.wargo@CNSw.com

ViaSAT Government Systems

6155 El Camino Real Carlsbad, CA 92009 760) 476-2200 www.ViaSat.com

Mike Kocin 760.476.2342 mike.kocin@viasat.com





Detailed Recommendations – Architecture & Design



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- Balance hardware and software in a software defined radio.
 - There is no need to accomplish everything in software.
 - Functionality that requires critical timing or other difficult performance parameters and/or are unlikely to change can be done in hardware.
- Security dictates a large portion of the architecture's partitioning.
 - Even in a commercial application anti-spoofing and anti-hijack will be a concern for air traffic control.
- FPGA's can replace ASICS until the design has matured enough and the market will warrant high enough production to justify their use.
- Avoid the use of threaded control throughout a system. Threaded control is a control structure that is implemented as a single level in the system touching every hardware device and requiring updating at every clock cycle.



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- Hosting multiple functions on processors (i.e. multi-tasking of a processor) causes significant complexity unless absolute independence can be established.
 - The first rule of thumb is to try and keep processor loading at or below specifications preferably at no more than 75% of maximum specifications.
 - Multiple functions create multiple integration issues if real time simultaneous functions are needed and software certification complexity increases significantly with each added block of functionality hosted.
 - Establishing deterministic independence for each waveform must be a high level goal.
- Spreading a single function across multiple processors limits performance, increases complexity, and adds test and qualification risk to the system.
 - Independent functionality will require independent software modules.



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- The design and objective of CORBA make's it a virtual patch panel.
 - Multi-level security will dictate separation of data
 - if not limited by privileged routing tables or other types of interconnection restrictions, then endless combinations will cause endless testing for certification.
- Designing with CORBA will require the use of extensions to be able to implement security.
 - These extensions are in the form of limiting what data can be connected to what processing element within the design.
 - This assures that multiple functions with different security levels can operate simultaneously in the same system without compromising security levels of any function.
- The MMDA process architecture should consider a layered approach. The radio implements only the lowest layers of the communication system.



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- CORBA implementation does have some performance issues associated with data marshalling.
 - Instead of moving data up and down the protocol stack, move data pointers. This will allow large blocks of data to be utilized in more efficient periods of time
- Implement a "field configuration" goal that allows the user to change the fundamental functionality of the radio to meet changing operational and/or environmental needs.
 - software to hardware processor interfaces need to be defined with no ambiguity.
 - The functionality of services provided for applications need to be defined, again with no ambiguity.



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- Since most of the future applications will be more data intensive, a significant increase in bandwidth is highly desirable. This can be a significant issue since the available spectrum, which is partitioned into smaller frequency blocks, is heavily utilized. These approaches to address these challenges can be considered.
 - Higher order modulations
 - The additional of spatial diversity, known as directional antennas
 - Utilize smaller portions or chunks in the unused or underutilized spectrum, creating the equivalent of a single broadband channel Orthogonal Frequency Diversity Multiplex (OFDM)
 - The utilization of time diversity through techniques like Time Division Multiple Access (TDMA)
 - The utilization of code diversity through techniques like Code Division Multiple Access (CDMA)